PATENT SPECIFICATION

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COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Improvements in or relating to Yarn Twisting

We, E.I. Du Pont De Nemours And Company, a Corporation organised and existing under the laws of the State of Delaware, United States of America, of Wilmington, State of Delaware, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to yarn production and handling, and is particularly concerned with twisting as-spun or zero-twist yarn in a continuous manner.

Twisting plays an important part in most textile operations. The need for true twist is due to both production and end-use considerations. True twist may be needed at relatively low levers, say about 1 turn per inch (tpi), to improve yarn handling characteristics, at the intermediate levels of about 6 to 12 tpi in the case of yarn to be used in most textile or industrial applications, and at higher levels, e.g. 30 or more tpi, to produce stretch yarns and the like. Such twist accomplishes several purposes, among the more important being to improve the mechanical handling qualities of the yarn, to compact the yarn bundle, to control fabric appearance and handle, and to increase yarn elasticity. As an alternative to twisting, the use of untwisted or "zero-twist" yarn in most cases is decidedly unattractive, owing mainly to the poor performance of such yarn in many of the common textile operations, such as winding, weaving, and knitting.

Although the need for twisting has remained unchallenged, it is a very expensive operation. Conventional twisting requires elaborate and expensive equipment which is costly and difficult to maintain, and is a low-output time-consuming operation, being neither a continuous nor a multi-end process.

It is estimated that using a conventional up-twister operating at a normal speed of 10,000 r.p.m., at least 11 working days are required to produce a single pound of 30 tpi 30-denier nylon yarn. Such low output not only increases the cost of the product, but creates a definite "bottleneck" in the otherwise rapid and continuous production of yarn. Moreover, the mechanical operations involved in true twisting often result in yarn of lower quality than might otherwise be expected.

It is apparent that many improvements in the continuous production of yarn would arise from a suitable method and apparatus for continuous, high speed true twisting which could form part of a continuous operation with the preparation of the yarn itself but the closest approximation to such twisting has been in conventional false-twisting as employed in the production of the so-called "Helanca" (Registered Trade Mark) stretch yarn. False-twisting apparatus is exemplified in United States Specifications Nos. 2,089,198, 2,089,199, 2,111,211, 2,463,620, and 2,741,893. Additional mechanical and pneumatic false-twisters are shown in Specification No. 447812 and United States Specifications Nos. 2,173,789, 2,475,922, 2,515,299, 2,526,775, and 2,751,747.

All known false-twisters operate in essentially the same manner. In the well-known process for producing so-called "Helanca" or stretch yarns, a twisted yarn segment is subjected to heat-setting conditions and then back-twisted. False-twisting in the absence of setting has in the past produced only zero-twist yarn, since the twist has been temporary and automatically removed as the twisted yarn passes through the twisting means. Accordingly, even though false-twisting permits the temporary accumulation

of twist in a running yarn, such twist is of a transitory nature, and the ultimate product of such a process is zero-twist yarn. False-twisting alone, therefore, is not a solution to the problems indicated hereinabove. (Truslow, "Handbook of Twisting" p. 40-41 (1957)).

Our Specification No. 871,112 describes a process for imparting a twist to a travelling filamentary material which comprises introducing the filamentary material axially into a yarn passageway having an equivalent diameter (as thereinbefore defined) of 0.002-0.125 inch, directing one or more gas streams having at least half sonic velocity into the yarn passageway in a non-axial direction against the periphery and eccentrically to the axis of the filamentary material while the latter is under tension not exceeding 25 grams, the ratio of the cross-sectional area of the yarn passageway to that of the gas stream or streams being from 4 : 1 to 1 : 10 (both areas being measured at the point of interception of the gas by the filamentary material) and the process conditions being such that the filamentary material is twisted at a rate of at least 50,000 turns per minute. Specification No. 871,112 also describes how an alternating twist yarn may be obtained by varying the tension on the filamentary material or by passing the gas stream in turn through two or more conduits which direct the gas against the filamentary material in opposing directions.

The present invention provides a process similar to that described in Specification No. 871,112, in which process a multi-filament yarn under a controlled substantially constant tension in a yarn passageway is subjected to one or more streams of compressible fluid having at least half sonic velocity and exerting a twisting action on the yarn bundle as a whole, and one or more of the process conditions is varied so that equilibrium twisting is substantially avoided.

The yarn obtained by the process of the invention is characterised by successive segments of alternating "S" and "Z" twist, and not only resists forces tending to remove the alternating-twist but also tends to return to the alternating twisted configuration after an applied tension sufficient to remove the twist has been released, and does return to the twisted configuration to a substantial degree. The alternating twist is stable even though the yarn may be completely free of foreign materials such as setting agents and adhesives. Of course, these stable alternating-twist yarns may be set with heat or other agents or treated with sizes or plasticizers, or partially melted and then solidified, or otherwise treated to cause adjacent filaments to cohere, but none of these treatments is necessary to produce the stable alternating-twist yarn of this invention. Sufficient stability results from the twisted and interlaced configurations of individual filaments and groups of filaments produced during treatment of the yarn by the twisting jet of fluid, and from frictional constraint between adjacent filaments within the yarn bundle. The twisting of individual filaments and groups of filaments within the yarn is random both in direction and amount and independent of the duration of the bundle twist.

The reason why an alternate twist yarn is obtained is believed to be as explained below, though of course the invention is not dependent on nor limited by the correctness of this explanation. In practising the invention the fluid twister is usually positioned between an upstream feed-point, e.g. a set of nip rollers or other suitable means, and a downstream take-up point, e.g. a winding package. If the filamentary material is passed through the yarn passageway and the gas stream is then directed against the periphery of the material, then initially the material assumes a twist in one direction between the fluid twister and the take-up point. If the process conditions remain constant, however, an equilibrium position is rapidly reached. At equilibrium the torque exerted by the twisted material between the feed-point and the twister is equal and opposite to the torque exerted by the gas stream; the material between the twister and the take-up point is therefore not twisted. This condition, conventionally called "equilibrium twisting," results in winding zero-twist yarn past the take-up point (unless the filamentary material supplied already contains a set twist, in which case this set twist will be retained). If, just as or before the process has reached the position of equilibrium under one particular set of process conditions, the process conditions are changed, the adjustment to the new equilibrium position will cause a length of (say) S twist to pass to the take-up point. If the previous process conditions are then restored, the readjustment to the first equilibrium position will cause a length of Z-twist to pass to the take-up point. An alternate twist yarn will thus be obtained. The lengths of alternate S and Z twist in the yarn so-produced may be randomly or regularly arranged, according to whether the variation of process conditions is irregular or periodic. The fluid stream not only imparts high speed rotation to the yarn bundle as a whole but also, because of the velocity gradient of the fluid stream across the yarn bundle, causes twisting and interlacing of the individual filaments of the yarn bundle. This helps to consolidate the yarn and to retain the alternating twist produced in the yarn.

If the yarn which is treated has no true twist, then the alternate twist yarn produced has a net bundle twist of zero, but if a true

twist yarn is used the true twist is retained in the product, the alternate twist being superimposed thereon.

Equilibrium twisting can be avoided by varying one or more of the process conditions. For example, the speed of the yarn may be varied; the velocity of at least one of the fluid streams exerting a twisting action on the yarn bundle may be varied; a plasticizing or sizing agent may be applied intermittently to the yarn before is passes through the yarn passageway; or the yarn may be traversed from side to side of the yarn passageway (this is referred to herein as the "multiple vortex" method).

The process of the invention permits the production of a stable alternate twist yarn in a rapid and continuous manner at speeds comparable to or greater than conventional drawing and spinning speeds, thereby allowing these separate steps to be combined into a single, efficient, high-speed operation. The alternating-twist yarn can be used in the place of conventional true twist yarn in a wide variety of applications.

The yarn can be subjected to the action of the streams of compressible fluid in a yarn passageway having an equivalent diameter of 0.002 to 0.125 inch, the ratio of the cross-sectional area of the yarn passageway to that of the fluid stream or streams being from 4 : 1 to 1 : 10, both areas being measured at the point of interception of the fluid by the filamentary material. The equivalent diameter of the yarn passageway is defined as the diameter of a circle having the same area as the cross-section of the yarn passageway.

When the yarn is traversed from side to side of the yarn passageway, the passageway preferably consists of two or more adjacent yarn passages which have their longitudinal axes substantially parallel, and which either overlap or are connected by a slot or slots through which the yarn can pass as it is traversed.

It is, of course, essential that the net effect of the fluid streams should be to twist the yarn bundle as a whole, but preferably at least one of the streams of compressible fluid exerts no twisting action on the yarn bundle as a whole when it is in its mean position. Such a fluid stream helps to consolidate the yarn by causing twisting and interlacing of the individual filaments, particularly at the points of twist reversal. The axes of the fluid streams may be perpendicular to the axis of the yarn passageway or inclined at an angle of up to 75° or even more from this perpendicular in order to exert a forwarding or braking action on the yarn.

The yarn passageway may be integral with the fluid conduits or the latter may be spaced apart from the yarn passageway but in position to direct fluid substantially tangentially to the inner periphery of the curved concave surface of the passageway. There may be a plurality of conduits directing fluid flow about the periphery of the concave surface or surfaces, and these conduits may be spaced longitudinally or circumferentially or both about each yarn passageway. Naturally, in order to obtain the highest rate of twisting, all fluid conduits, where there are more than one, should be directed in substantially the same tangential direction. It is not necessary, however, that the longitudinal axes of all the fluid conduits lie in the same or parallel planes with respect to the axis of a given yarn passageway; on the contrary one or more may have axes perpendicular to the axis of a yarn passageway while one or more others may have axes inclined to impart both forwarding and twisting motion to the yarn while other fluid conduits may have axes inclined backward along the axis to exert a braking action. In the case where there are a plurality of fluid conduits supplying fluid to a yarn passageway, it may be desirable to provide one or more exit ports along the passageway, and these may be positioned at any convenient points.

The yarn passageway may be cylindrical over substantially its whole length, or it may have a smooth non-circular cross-section over part or all of its length.

The invention is illustrated in the accompanyiny drawings, wherein :—

Figure 1 illustrates an alternating-twist yarn of this invention.

Figures 2 to 4 show various forms of fluid twister which may be utilised in the present invention. (Additional examples of fluid twisters which may be used are described in Specification No. 871,112).

Figures 5 to 7 illustrate various assemblies for carrying out the process of the invention.

Figure 8 is a graph showing various characteristics of an alternating-twist yarn.

Figure 9 illustrates "snarling."

Figure 10 shows the structure of a stable alternating-twist continuous filament yarn when the yarn bundle is forceably divided.

Figures 11 to 14 are graphs showing twist retentivity of yarns of this invention.

Figures 15 to 24 show various embodiments of fluid twisters which may be utilised in the embodiment of the present invention in which the yarn is traversed.

Figure 25 illustrates a complex alternating-twist yarn prepared according to this invention having short sections of interlaced yarn at the reversal points "a."

In the drawings like numbers appearing in the various figures represent similar structures, although the shape or form of the structure may vary from one Figure to the next.

Referring now to Figures 2 to 4, these illustrate fluid twisters 50 each having a yarn passageway 51 intercepted by one or more fluid conduits 52 and exhaust ports 56. Figures 2 and 3 illustrate representative fluid twisters useful in this invention, comprising an axial yarn passageway 51 which is substantially cylindrical in form throughout its length. A fluid conduit 52 intercepts the yarn passageway at 53 and is positioned so that its longitudinal axis does not intercept the longitudinal axis of yarn passageway 51, as shown in Figure 2. When gas under pressure is passed through fluid conduit 52 so that it reaches at least ½ sonic velocity upon emerging into the yarn passageway 51, the force of the gas jet opens up the yarn and separates the filaments momentarily while simultaneously applying torque to the yarn bundle to produce a high rate of twisting. At high fluid velocities, less dense fluids can be employed to obtain substantially the same torque as is produced by a higher density fluid travelling at lower velocity. Fluid may be supplied to the fluid conduit 52 by any convenient means. Preferably, the yarn passageway will have rounded edges at both ends to minimize tearing of the yarn bundle, and is widened by bevels 55 at the yarn entrance and exit ports. Naturally, it is not necessary that these widened portions of the yarn passageway be symmetrical or even similar in shape.

In some instances as, for example, when the yarn passage is of substantial length, it is desirable that the yarn passageway contain one or more fluid exhaust ports in order to facilitate removal of fluid from the yarn passageway. According to a particularly preferred embodiment, the fluid twister may be designed to provide for ease in threading up by providing a string-up slot running the entire length of the yarn passageway. The string-up slot may simultaneously serve as an air conduit or exhaust port, if desired. Any of the fluid twisters can be adapted to provide string-up slots. Figures 15 to 18 show twisters having in addition a string-up slot 57 which is effectively closed in operation by the air or other compressible fluid employed.

Figure 4 shows a "double vortex" twister which is capable of alternate twisting while utilising a unidirectional air supply. This fluid twister is used in combination with conventional reciprocating traverse means and contains overlapping yarn passageways 51a and 51b, which are substantially cylindrical in form throughout their lengths. Fluid conduit 52 intercepts both yarn passageways and is positioned so that its longitudinal axis does not intersect the longitudinal axes of yarn passageways 51a and 51b, but intersects the line of intersection of the passageways. When gas under pressure is passed through fluid conduit 52 so that it reaches at least ½ sonic velocity upon emerging into the yarn passageway 51, the force of the gas opens up the yarn and separates the filaments momentarily while simultaneously applying sufficient torque to any yarn in the yarn passageway to produce a high rate of twisting. The path of fluid flow, i.e. vortex formation, is shown by the arrows. Preferably in this apparatus also one or both of the passageways is provided with a string-up slot (not shown in Figure 6).

Figures 15 and 17 to 24 show cross-sectional views of additional multiple-vortex fluid twisters taken along the axes of the fluid conduits. These figures illustrate the manner of interception of a yarn passageway 51 by one or more fluid conduits 52 and exhaust ports 56 and also show various forms which yarn passageway and fluid conduit may assume.

Figure 15 shows a fluid twister 50 having an air-curtained string-up slot 57. Fluid conduits 52a and 52b intersect the slot 57 in a downward direction; the convergent fluid stream intersects the yarn passageways 51a and 51b at 53.

Figure 16 is a perspective view of the fluid twister of Figure 15 and shows yarn 14 passing therethrough in the direction indicated by the arrowheads. In operation, downstream traversing causes the yarn alternately to be in yarn passageway 51a (position 14a) and in yarn passageway 51b (position 14b). Now according to Figure 15, fluid flows in a counterclockwise direction in yarn passageway 51b. Thus, yarn 14 in Figure 16 is twisted in the "S" direction upstream and in the "Z" direction downstream when it is in yarn passageway 51a (position 14a) and in the "Z" direction upstream and the "S" direction downstream when it is in yarn passageway 51b (position 14b). The same relationship obtains when upstream traversing is utilised; the converse holds when opposite-hand fluid twisters (see Figure 18) are employed.

Figure 17 shows a fluid twister similar to that of Figure 15 but with fluid conduits 52a and 52b offset with respect to each other.

Figure 18 is a similar "offset" fluid twister in which fluid conduits 52a and 52b are "crossed" so that the fluid flow in each of yarn passageways 51a and 51b is in a direction opposite to that in the fluid twisters of Figures 15 and 17.

Figure 19 shows a fluid twister with four yarn passageways 51a-51d.

The fluid twister of Figure 20 has yarn passageways 51a and 51b spaced apart, but interconnected by a lengthwise slot.

The half-twister 51a of Figure 21 can be used in place of half-twister 51a or 51b of Figure 20 to provide fluid flow in the same direction in both yarn passageways.

Figure 22 shows an exceptionally simple fluid twister wherein the two fluid vortices exist in a single yarn passageway.

Figure 23 shows a fluid twister particularly adapted for interlacing yarn at twist reversal points. In this embodiment, an intermediate yarn passageway 51c is perpendicularly intercepted by fluid conduit 52c, rather than tangentially as in the case of the laterally extreme yarn passageways 51a and 51b.

Figure 24 shows the twister of Figure 23 modified to provide enhanced interlacing, by the addition of fluid conduit 52d which also perpendicularly intercepts yarn passageways 51c, and which has a longitudinal axis in common with fluid conduit 52c.

The above-described fluid twisters are suitable for twisting a large variety of filamentary structures, including staple and continuous multi-filament yarn, thread, fibres, roving strands, and the like. Yarn will be employed throughout the instant disclosure as exemplary of all such structures, since in the twisting of yarn the invention has its greatest utility. The yarn may be composed either partially or entirely of synthetic polymeric materials, such as the polyamides (nylon), e.g. poly(ζ-caproamide) and poly-(hexamethylene adipamide); polyesters, e.g. poly(ethylene terephthalate), the terephthalate polyester of trans-1,4-cyclo-hexanedimethanol (alternatively named trans-bis-1,4(hydroxymethyl) cyclohexane), or poly(ethylene terephthalate / isophthalate) (89/11%); acrylic polymers, such as poly-(acrylo-nitrile) and/or the many copolymers thereof; vinyl polymers, e.g. poly(vinyl chloride), poly(vinylidene chloride), and copolymers thereof; elastomers; and hydrocarbon polymers, such as polyethylene and polypropylene. On the other hand the yarn may be based on or consist of naturally occurring materials, e.g. it may be made of a cellulose ester, regenerated cellulose (rayon), regenerated protein, cotton, wool, silk, glass or asbestos.

In the so-called "multiple vortex" method, in which the yarn is traversed, the yarn traverse means may be positioned upstream or downstream from the twister, and preferably is a conventional reciprocating traverse located downstream from the twister at the take up point, e.g. at a package wind up.

Fluid pressure, yarn tension, and traverse cycle frequency are the most important process variables in the practice of the invention utilising a multiple-vortex twister. The traverse cycling determines to an appreciable extent the nature of the product, and is of course arranged to avoid equilibrium twisting and hence to produce alternate twist yarn. Moreover, under a given set of conditions, the traverse cycle determines the level of twist in the yarn as a fraction of the equilibrium twist level and, therefore, affects the average twist level in the product. The average level of twist also depends on the yarn tension and fluid pressure, to which it is respectively inversely and directly proportional. At a given yarn speed, the traverse cycle determines the length of yarn over which twist of a given direction is imparted and, therefore, affects the twist period in the product. Finally, the traverse cycle frequency will determine the gross characteristics of the product. At relatively low traverse frequencies, say less than 25 cycles per second (cps), the product is an alternating-twist yarn which exhibits excellent uniformity of twist level and periodicity. On the other hand, if the traverse frequency is too high, say greater than 50 cps at conventional yarn speeds, the product is an interlaced yarn substantially free of alternate twist. At intermediate traverse frequencies, say between 25 cps and 50 cps, the product is an interlaced alternating-twist yarn as illustrated in Figure 25. The last-mentioned product differs from interlaced yarn to which is subsequently imparted an alternating twist, as described in our Specification No. 26,230/59 (Serial No. 924089) in that the density of interlacing varies along the length of the yarn, tending to be most dense at the points of minimum twist, thereby enhancing the stability of the product. The interlacing effect is most pronounced when using the apparatus of Figure 23 or 24, where the product even at traverse frequencies below 25 cps also is an alternating-twist yarn having interlaced twist reversal segments.

By suitable determination of the traverse cycle frequency, the process of this invention may be practised using the multiple-vortex twisters to produce an exceptionally uniform stable alternating-twist yarn or a stable alternating-twist yarn having interlaced twist reversal segments. In the absence of traversing and utilising a pulsating fluid supply, the multiple vortex twisters may be used to twist two or more yarn ends simultaneously, adjacent ends having their respective twist profiles completely out of phase with respect to one another.

As noted above a stable alternating-twist yarn can also be produced with continuous unidirectional application of twisting by systematically varying the speed of the yarn, or by intermittent upstream setting, e.g. by the intermittent application of heat or size to the running yarn. The effectiveness of this method is dependent upon the range of speed variation, its period with respect to the yarn tension, and the effect of varying speed on the twister. Yarn speed and tension may be concomitantly varied to increase the effectiveness of the separate operation. The variation of tension is greatly increased by using the fluid twister of Figure 4, whereby the traverse stroke causes the yarn alten-

nately to be twisted in yarn passageway 51a (clockwise twisting) and yarn passageway 51b (counterclockwise twisting). Using the fluid twister of Figure 4, the associated traverse means may be located either upstream from the twister, e.g. at 31 in Figure 7, or downstream therefrom, e.g. at the winding point 18-19. Upstream traversing may also be used to provide intermittent sizing or setting with the means 32 and 33 respectively, of Figure 7 located in a fixed position downstream from the reciprocating traverse means located at, e.g. 31.

The most versatile of the methods of the invention involve intermittent unidirectional or two-directional twisting in a multiple-vortex jet, because of the simplicity of the apparatus, ease of operation under a wide variety of conditions of yarn speed and tension, and uniformity of the product.

Twisting in accordance with this invention leads to yarn having segments of twist in one direction, each positioned between segments containing opposite twist. All segments usually contain about the same length of yarn, and about the same amount of absolute twist. The net twist in the yarn is essentially zero, that is, the total "S" twist is equal to the total "Z" twist. The resulting yarn is a stable alternating-twist yarn. An exaggerated alternating-twist yarn is shown in Figure 1.

Figure 8 shows graphically the lengthwise variation in twist along the length of a segment of an alternating-twist yarn of this invention wherein ordinate oS indicates level of "S" twist and ordinate oZ indicates level of the "Z" twist at any point along the yarn length, i.e. the abscissa oL. At the start of twisting (at o), the "S" twist level rises rapidly to a maximum (a), then, approaching equilibrium twisting, falls off towards b. The rate of twisting is altered at b, allowing the upstream accumulation of twist to pass downstream and onto the beam. Such practice results in "Z" twist rising to its maximum twist level at c, then, again approaching equilibrium twisting, falling off towards d, at which point twisting in the "S" direction is initiated by again changing the rate of twisting, and the process commencing as at o is repeated. By suitable variation of processing conditions, the curve of Figure 8 can be made to assume a variety of shapes which, of course, need not be symmetrical. Note that as the twist level rises from o, the yarn cross section becomes substantial circular, whereas zero-twist yarn (at o) has a ribbon-like cross section.

Characteristics useful for describing a stable alternating-twist yarn are the "twist period," "maximum twist," and "average twist." "Twist period" (also known as or cycle length) is the distance along the threadline that contains a complete section of both "S" and "Z" twist. A length of yarn containing twist in but one direction ("S" or "Z") is described as the "increment length" of twist. The "average twist" level is defined as the absolute numerical average of twist per unit length, taken over a representative sample length of yarn ((several twist periods), regardless of twist direction. "Maximum twist" is the largest amount of twist (in turns per inch) encountered in an "S" or "Z" twist section. The three parameters are interrelated by the generality that average twist approaches the maximum twist value as twist period decreases. The curve of Figure 8 tends to "flatten" as the ratio decreases (see equation 1). Referring to Figure 8, the twist period is the length of segment od; "increment length" of twist is the length of segments ob and bd; "maximum twist" is indicated at a or c, and "average twist" is given by dotted line o'L'.

Figures 5 to 7 show various assemblies in which the fluid twister may be used to twist yarn continuously into a stable alternating-twist yarn. Figure 5 illustrates schematically a string-up assembly for twisting yarn immediately after spinning and prior to packaging. Filaments 11 issue from spinneret 12, and converge at guide 13 into yarn 14, to which finish is optionally applied (by means not shown) before it passes the nip rolls 15, which serve as snubbing means and the feed point for twister 16. After twisting, the yarn 14 passes idler roll 17 and then moves to the takeup point, a backwindable package 18 driven by drive roll 19.

Figure 6 illustrates schematically a string-up assembly whereby yarn is twisted immediately after drawing and prior to packaging. In accordance with this embodiment, undrawn yarn 14 is withdrawn from package 20, passes through pigtail guide 21, then is passed in multiple wraps about a driven feed roll 22 and its assoicated separator roll 23. In a highly preferred embodiment, yarn is supplied directly to guide 21 from a spinning position (see Figure 5) rather than a package. From feed roll 22 the undrawn yarn makes one or more wraps about a snubbing pin 24 and is drawn in frictional contact therewith under the urging of draw roll 25 and its associated separator roll 26. Draw roll 25, of course, has a higher peripheral speed than feed roll 22, so that the yarn is elongated to several times its original length. From draw roll 25, which serves as the feed point, the yarn passes twister 16, is twisted as directed hereinabove, then passes idler roll 17 to the package 18 driven by drive roll 19. Twisting in both Figures 5 and 6 may be either intermittent unidirectional or two-directional; uniform alternating-twist yarn is wound onto package 18 in both cases.

In another preferred embodiment the yarn,

after twisting, may be passed to the takeup point in the string-up assembly of either Figure 5 or 6, without passing the idler roll 17. In such a modification of Figures 5 and 6, the traverse means are made a part of the wind up assembly 18-19; specifically, drive roll 19 is of the self-traversing variety (United States Patent Re. 23,977). Other traverse means are applicable, such as reciprocating guides located either upstream or downstream from fluid twister 16. Also, it is preferred that guide means be present to provide a pivot point for the traversing yarn within the fluid jet. In the preferred embodiments of Figures 5 and 6, such action is derived from the yarn advancing means, the nip rolls and draw roll, respectively.

Figure 7 illustrates a string-up assembly whereby an alternating twist yarn is produced continuously from filament yarn by varying the rate of twisting through intermittent setting and/or sizing. In the schematic drawing of Figure 7, yarn 14 supplied from either a spinning position, as shown in Figure 5, or from a package, as shown in Figure 6, passes guide 13 or 21, and then travels to nip rolls 15. Alternatively, staple roving 27 unwound from package 28 passes in sequence through a trumpet guide 29, the drafting rolls indicated at 30, and nip rolls 15. The strand 14 or 27, as the case may be, then encounters the traversing means 31, size applicator roll 32, setting means 33, and the eyelet guide 34; then is twisted by fluid twister 16 and passes to package 18 driven by roll 19. Size applicator roll 32 revolves in a bath of size or adhesive solution, and is arranged so that size may be applied intermittently to strand 14 or 27. Setting means 33 may be a hot plate or other suitable heating means such for example as a hot pin or pipe, a steam tube, an oven, a hot liquid bath, or a infrared radiator. The yarn may be plasticized in the absence of heat as, for example, with solutions of chemical plasticizers or similar materials. When plasticizing is effected with heat, the temperature of the heating medium must be regulated so that the yarn temperature does not reach the melting point of the yarn material. It is quite possible, of course, that the heating medium temperature or source of heat be above the melting point of the yarn if yarn speeds are such that the yarn temperature is maintained below its melting point. Temperatures lower than the second-order transition temperature of the yarn material should usually not be employed because, under these conditions, any setting of the filaments is not permanent and the utility of the product is reduced. Setting means utilizing dry heat may be used in combination with size applicator 32 to facilitate drying the size solution applied thereby. Eyelet guide 34 serves to centre the strand 14 or 27 in twister 16 in the case where the strand tension is varied by upstream displacement. Twister 16, when used in the various arrangements permitted with the apparatus of Figure 7, may be operated continuously without changing the direction of twisting.

Air at room temperature is preferred for twisting yarn in the fluid jet device of this invention, but the air may be heated or refrigerated, if desired. Low pressure steam may also be used where its plasticizing action, if any, is not harmful. Other gases substantially inert to the yarn, such as carbon dioxide and nitrogen, may be utilized, if desirable. The invention is illustrated using air as a fluid because air is preferred in carrying out the process of this invention, but any inert fluid is suitable providing its plasticizing action, if any, is less than that of any upstream plasticizing step utilized. Mixtures of fluids also may be utilized. In order to operate the process in accordance with the invention, it is necessary that the fluid, for example air, immediately prior to impinging upon the yarn reach a velocity of ½ sonic velocity or more, so that depending on the diameter of the yarn passageway, twisting speeds of between about 200.000 and about 2,000,000 revolutions per minute are easily obtained. For this purpose, air at a pressure of at least 10 psig is usually sufficient, with a pressure about 15 psig or more preferred, when operating at normal yarn tensions. Even lower pressures may be employed in those cases where the yarn tension is of a low order.

It is preferred that yarn tension be of a low order, and tensions less than 30 grams are desirable in most applications. Lower tensions, say between 0.1 and 15 grams, are preferred, and for the most efficient twisting action at the highest twisting rates and yarn throughput, the tension of the yarn should be maintained between 0.5 and 10 grams. Tension during twisting should be sufficient to prevent "twist doubling," as illustrated in Figure 9.

Whereas the average twist level in an alternating-twist yarn is controlled primarily by tension and fluid pressure, the twist period is determined by the "duration of twisting," i.e. the time interval during which twist of one direction is being accumulated in the yarn as it passes the take up point, which, in turn depends on the method by which the rate of twisting is varied. The duration of twisting depends upon the frequency with which the process conditions are changed. The duration of twisting determines the length of the yarn segment over which twist of a given direction is accumulated, and hence also determines the twist period except during conditions of equilibrium twisting (which is to be avoided. Although

there exists no theoretical upper limit for the twist period, or more precisely, the increment length of the twist, there is a practical upper limit, determined by the distance between the twister and the first upstream snubbing guide, which tends to inhibit the further upstream accumulation of twist. Therefore in practice twist is confined to the yarn segment between such a snubbing guide and the twister, and since only a certain amount of twist may be accumulated before the upstream twist counteracts the twister (at initiation of equilibrium twisting), the upper limit of the period is thereby limited. The above variables are related through the equation

$$\frac{S}{L_u} D = \ln \frac{T}{T - t_u S} \qquad (1)$$

where S is the yarn speed in yards per minute, L_u the upstream distance in inches from the twister to the first snubbing guide, T is the twisting speed in turns per minute, t_u is the upstream twist level in turns per inch, and D is the duration of twisting in seconds, i.e. time interval following the initiation of twisting to the point where t_u is achieved. Since the equilibrium upstream twist level is given by the expression T/S, it is possible to determine D so that t_u does not exceed about 0.9 T/S, thereby avoiding a condition of equilibrium twisting and, therefore, permitting production of an alternating-twist yarn having excellent uniformity of twist level and twist period. D is dependent upon the ratio S/L_u. In the particular application utilizing a multiple vortex twister, D depends also on the traverse cycle C, i.e. the time required for one complete traverse stroke and return stroke. Since the yarn is in each of the end yarn passageways for a time of about ½ C, it follows that the quantity ½ C should be determined so that t_u does not exceed about 0.9 T/S if a condition of equilibrium twisting is to be avoided. The practical significance of this relationship is that the S/L_u ratio increases, i.e. as the yarn speed increases or the upstream distance decreases, the time after initiation of a given twisting cycle required to achieved equilibrium twisting decreases, hence D under such conditions should be correspondingly reduced to avoid the production of zero-twist yarn. Where D exceeds the time required to achieve equilibrium twisting, an alternating-twist yarn is produced containing sections of zero-twist yarn between sections of "S" and "Z" twist respectively.

The nature of the yarn being twisted influences the rate of twisting. The ratio of yarn diameter to the diameter of the yarn passageway of the twister determines to some extent the nature ("direct" vs. "reverse twisting") and efficiency of twisting; the ratio of the two quantities in that order should be from about 1 : 2 to about 1 : 10, and preferably about 1 : 4. The torsional modulus of the yarn determines the twist level at a given tension value. Thus, when comparing the upstream twist behaviour of 70 denier, 34 filament yarns composed of poly(hexamethylene adipamide) and poly-(ethylene terephthalate) during a condition of equilibrium twisting, it is observed that at comparable tensions (6 gm.), an average twist level of about 30 tpi, as compared with 50 tpi, respectively, are obtainable under the same twisting conditions. Moreover, at reduced yet still comparable tensions (2 gm.), and with the same twisting conditions, "snarling" (Figure 9) is seen in the latter yarn, whereas none is observed with the former. The effective torsional modulus of the yarn may be diminished by the application of heat and/or other plasticizing means. Thus, under the condition of twisting referred to above, and at 2 grams tension, the same poly(ethylene terephthalate) yarn may be twisted at 180°C. to more than 100 tpi without the occurrence of twist doubling. Yarn may be conveniently heated during processing by utilizing the means indicated at 33 in Figure 7.

The nature of the process of this invention makes certain demands upon associated equipment. As mentioned, an alternating twist is "trapped" or confined by a snubbing-type guide, e.g. pinch rolls or nip rolls. Twist ordinarily cannot pass upstream from such a guide. In addition, such guides as the yarn may encounter downstream from the twister preferably should be of the non-snubbing variety, such as eyelet guides, comb guides, and freely rotating idler rolls. The roll 17 in Figures 5 and 6 is of such freely rotating operation. Where downstream tension variation is used to produce alternating twist, the roll 17 or its equivalent should be omitted so that such variations are relayed to the twister without diminution or damping. Upstream from the twister, the location of the first snubbing guide determines the maximum increment length of twist. Referring to Figures 5 and 7, nip rolls 15 serve in that capacity; in Figure 6, draw roll 25 satisfactorily contains the upstream twist accumulation. Optionally, eyelet guides may be positioned approximately the same distance upstream and downstream, respectively, from the twister to permit accurate coaxial entry and exit of the yarn to and from the twister. Such practice tends to minimise fluctuations in the yarn line due to the influence of fluid exhausting from the twister. One such guide is shown at 34 in Figure 7. In so far as the distance L_D from the twister to the take up point is concerned, it is preferred that that value be minimised. It has been shown that as the ratio L_u/L_D increases, the down

stream twist level, as measured at the take up point, also increases with respect to the maximum obtainable upstream twist level. A high value of L_u/L_D is achieved by positioning the twister at about the take up point, e.g. the twister could be made a part of the traverse guide. Of course, when the traverse is part of the wind up, the twister should not be located so near the take up point that the yarn is snubbed at the twister by the traverse. On the other hand, the twister should be located sufficiently close to the traverse means so that the yarn is displaced thereby from vortex to vortex within the twister.

The alternating-twist yarn of this invention may be backwound in such a manner as to remove or retain twist, as required, although the structure is surprisingly retentive in most operations. Twist can be removed if the free suspended length of yarn during backwinding or any subsequent textile operation is allowed to exceed the twist period, while at sufficient tension. By "free suspended length" is meant the length of running yarn tensioned between two snubbing-type guides, e.g. between a package and a snubbing guide. If shorter lengths of yarn are freely suspended, twist removal is incomplete. Since some twist is contained by acute snubbing, when such a guide is encountered during backwinding, some twist will tend to accumulate and be concentrated upstream from such a guide. Twist of the opposite direction will also run into that region, leading to some twist cancellation. Accordingly, by suitable positioning of snubbing guides with respect to the package during backwinding, twist removal may be accomplished. Completeness and efficiency of alternating-twist removal is governed by the tension applied and the free-suspended length of yarn.

If it is desirable that twist be completely retained during backwinding it is obvious that the above-mentioned conditions are to be avoided. Therefore, to retain twist during backwinding or during any subsequent textile operation, the free suspended length of yarn should be kept low, the use of acute snubbing guides or the like means avoided, and tension should be maintained at the lowest sufficient level. The retention of twist may be further assured by utilizing a higher average twist level initially, or by increasing the twist period, or both. Twist may also be "set" by twisting the yarn in the plastic state (via heat or residual solvent) followed by cooling, by slashing the as-twisted yarn, or by the application of size or an adhesive during twisting. The average twist level can be increased by increasing the fluid pressure or reducing the yarn tension or both. Increasing the average twist level is preferred to increasing the twist period, since by the latter method the reversal length between segments containing twist in opposite directions tends to increase. Such exaggerated sections of yarn having little or no twist are subject to the same difficulties during backwinding as is zero-twist yarn.

Alternating twist also is rendered more retentive by interlacing over the segments of twist reversal, an operation which "locks in" twist. The twist in such a yarn may later be removed or made "lively" by tensioning the yarn, provided that sufficiently high tensions are used. Thus, by preparing an alternating-twist yarn with interlaced reversals (Figure 25), the advantages of both types of yarn are achieved in a single structure, i.e. a yarn having the elasticity or twist liveliness of a stable alternating-twist yarn, and the retentivity of structure characteristic of an interlaced yarn. Of course, all the yarns prepared in accordance with this invention possess random filament twist, as is characteristic of fluid twisting.

A surprising degree of twist retentivity is observed with the yarns twisted in accordance with this invention, and this is believed to be due to the twisting of individual filaments and groups of filaments, in addition to twisting of the yarn bundle. As a result of this, twist is retained during such textile operations as slashing and weaving, provided that excessive tensions are not encountered.

The invention is illustrated by the following Examples.

EXAMPLE 1

An alternating twist yarn is prepared by the intermittent application of unidirectional twisting. The fluid twister of Figures 2 and 3 is employed, and the yarn is twisted immediately after drawing, using the apparatus of Figure 6.

The dimensions of the twister are as follows:—

	LENGTH	*DIAMETER*
Exhaust Section 56	0.24 inch each	0.150 inch
Bevelled Section 55	60° bevel	
Twister Section 51	0.245 inch	0.050 inch
Fluid Conduit 52		0.020 inch
TOTAL	0.875 inch	

Air is supplied to the twister intermittently by a rotary valve (not shown), working at 250 r.p.m., which permits air to flow to the twister during ½ of each cycle of revolution.

An 840 denier, 140 filament yarn of poly-(hexamethylene adipamide) is twisted at 500 ypm, 35 grams tension. Results obtained at several pressures are indicated in Table 1.

TABLE 1

AIR PRESSURE (*psig*)	*AVERAGE TWIST LEVEL* (*tpi*)
10	0.5
20	0.8
30	1.3
40	2.0
50	2.9

The twist period is uniform (72 inches) throughout this test. It is observed from these results that as the air pressure on the yarn increases, the average twist level risse.

Alternating twisting in a fluid jet improves the quality of yarn after drawing, since any broken filaments incurred during drawing are twisted back into the yarn bundle, elimating subsequent filament stripbacks and wraps. This feature of the instant infention is shown in the following tests made on 150 denier, 40 filament cellulose acetate yarn, intentionally degraded to form loops, broken filaments, and the like defects. The number of defects is counted immediately before and after twisting to profide a quantitative measure of the quality improvement in the yarn obtained from the twisting process. The yarn is twisted to an average twist level of about 1.5 tpi, and gross yarn defects are measured using the detector shown in United States Specification No. 2,841,048. These results are shown in Table 2.

TABLE 2

	DEFECTS COUNTED	
Yarn Tested (*Yards*)	*Before Twisting*	*After Twisting*
3900	20	0
3100	20	2
2400	20	2
8000	20	2
1600	20	3
8100	20	3
9200	20	7
12000	20	1
3300	20	3
9400	20	7
——	—	—
AVERAGE: 6100	20	3

EXAMPLE II

The apparatus of Figure 7, employing the fluid twister of Figures 2 and 3 is used to twist 150 denier, 40 filament textile rayon taken from supply package 20. The yarn passageway is 0.063 inch in diameter, as is the fluid conduit. The twister is operated continuously with 40 psig air. An eccentric cam having a ¼ inch throw is located at 31, the applicator roll 32 is used to apply a ½% aqueous solution of carboxymethyl cellulose, and the hot plate 33 (1/16 inch x 13 inches) is maintained at 160°C. The yarn tension is controlled at 3-4 grams, the feed speed is 22 ypm, and the take up speed at 16 is 17 ypm. Rotation of the eccentric cam at 31 causes size to be applied on alternate 1½ inch lengths of yarn, with unsized segments of the same length between each pair of sized segments. The product thus has a twist period length of 3 inches, and is prepared at an average twist level of 10 tpi.

When auxiliary means are used to apply a plasticizer, in this case water, to the unsized segments, the twist period length remains 3 inches, but the average twist level increases to 20 tpi. By extending these techniques, yarns of any desired twist periodicity can be made having an average twist level up to 100 tpi. Also, this method permits preparation of yarns with unequal increment lengths of twist, by adjusting the relative dwell time of the yarn on the applicator roll 32. However, the twist period is unaffected by changes in dwell time and is controlled by the speed of the eccentric, decreasing as the frequency of reciprocation increases. In the case of unequal increment lengths within the period, a necessary consequence is that the twist level will not be the same in each increment. This method of intermittent size application during continuous unidirectional twisting is one of the most effective ways of obtaining very high levels of twist and precise period and increment lengths of twist. This technique also is applicable to staple yarn and drafted staple fibres. Interesting decorative yarns are prepared in the same manner by plying yarns of different colours, ad then processing according to this Exampe.

EXAMPLE III

The apparatus of Figure 7, less the members 31-34, is used to prepare an alternating-twist yarn during continuous unidirectional twisting by systematic variation of the speed of the yarn. A 70 denier, 34 filament poly(ethylene terephthalate) yarn is taken from supply packaeg 20 through feed rolls 15, twister 16, and thence to the take-up means 18-19. The twister is located as close as possible to the take up means to maximize the ratio L_u/L_D, 30 in this case. The motors driving both the feed and take up rolls are of the variable speed variety and are controlled by a common regulator. The initial feed roll speed is 100 ypm, the corresponding take up roll speed is 85 ypm. The secondary feed roll is 60 ypm, the corresponding secondary take up roll speed is 51 ypm. The rolls operate in synchronous manner intermittently at the two speed levels. The twist period of the yarn is proportional to the frequency of the speed changes with 90 psig air supplied to the twister, the average twist level is about 2 tpi. By the same method, the average level of twist can be varied between 0.5 and 10 tpi. This method can also be effected by using a ten-

sion gate instead of the feed rolls, a fluid twister, and an elliptical take up roll, to provide speed variation. The twist level in this latter method depends on the ellipticity of the take up roll; the twist period depends on its cycling.

EXAMPLE IV

A 70-34 denier filament poly(ethylene terephthalate) alternate twist yarn is subjected to the tensions shown in Table 3 at the free suspended lenghs indicated, with the resulting effects on the average number of turns per inch in the yarn.

TABLE 3

TENSION (*grams*)	*FREE SUSPENDED LENGTH* (*periods*)	*TURNS PER INCH*
3	3	1.1
6	12	0.8
12	0.75	0.75
12	3	0.6

Table 3 shows that the alternating-twist yarns of this invention have very surprising twist retentivity particularly when compared with mechanically false twisted yarn which has relatively negligible twist retentivity. One possible explanation for the twist retentivity of the yarns of this invention is the random twist of individual filaments and groups of filaments within the bundle as shown by Figure 10 which illustrates the appearance of a typical alternating-twist yarn of this invention when an attempt has been made to separate the filaments transversely. For the purposes of this invention it is necessary that the alternating-twist yarn have an average level of twist sufficiently high to provide the yarn with the cohesiveness and runnability of a true twisted yarn having at least 0.5 turn per inch true twist, that is, that the alternating-twist yarn be capable of being processed in a practical commercial process and be suitable for processing in any conventional textile yarn process in which true twist yarn having 0.5 turn per inch is processed.

EXAMPLE V

The "double vortex" fluid twister of Figure 18 is utilized to twist 75 denier 24 filament cellulose acetate yarn. The twister 50 has two 0.030″ diameter yarn passageways 51a and 51b which are ¼″ long and have their respective centres spaced 0.030″ apart. The fluid conduits 52a and 52b are 0.022″ in diameter; the fluid actually intersects the yarn passageways from .032″ by .017″ slot 53. The yarn string-up slot 57 is 0.004″ wide. The yarn is forwarded from a spinning position (as shown in Figure 5, omitting idler roll 17) to the twister located about equidistant from nip rolls and a traversing drive roll wind up at 617 yards per minute (ypm) under 10 grams tension, and is traversed at about 15 cycles per second (cps). The alternating average twist level in turns per inch (tpi) and period at various air pressures is indicated in Table 5A.

TABLE 5A

RUN	*AIR PRESSURE* (*psig*)	*AVERAGE TWIST* (*Tpi*)	*TWIST PERIOD INCHES*
1	10	1	23
2	20	2	20
3	30	2.3	23
4	40	2.5	23
5	50	2.5	23

These results show that with increasing air (fluid) pressure, the alternating-twist level increases and the period length remains about the same. With an increase in traverse cycle frequency, the period length decreases. With an increase in tension, the average twist level decreases. The product in all cases is exceptionally uniform. Table 5B shows results obtained with the above condition of Run 2 by varying the traverse cycle frequency.

TABLE 5B

RUN	*TRAVERSE FREQUENCY CPS*	*AVERAGE TWIST* (*tpi*)	*TWIST PERIOD INCHES*
6	5	1.5	74
7	10	2	37
8 (2)	15	2	23
9	20	2	19
10	25	1.5	15

The results in Table 5B show that as the traverse cycle frequency increases, the twist period decreases.

A stable alternating-twist yarn of 75-24 cellulose acetate is passed through a Saco-Lowell "Positrol" slasher without slashing fluid so as to simulate the tension and suspension conditions of ordinary slashing while eliminating slashing fluid which would tend to hold the twist in the yarn. The yarn passing through the slasher is subjected to gradually increasing tension and the changes in average twist level noted. The results are as follows:

TABLE 5C

TENSION (grams/denier)	*AVERAGE TWIST LEVEL (tpi)*
0 (approx.)	2
10	1
20	1
30	0.5

The twist retentivity of the alternating-twist structure of the yarns of this invention is illustrated by electrically recorded graphs of Figures 11-14, in which retentivity is indicated by the amplitude of the wave forms at tensions of 0, 10, 20, and 30 grams, respectively.

The above apparatus is used in combination with auxiliary means to provide higher speed traversing but with conventional wind up assemblies, thereby retaining quality of package formation at a high level. A vibrating reed is employed. The following Table 5D shows the preparation of the numerous products prepared by this method. Air pressure, tension, and yarn (75/24 cellulose acetate) speed are uniform throughout the series, 25 psig, 12 grams, and 617 ypm, respectively.

TABLE 5D

RUN	*TRAVERSE CYCLE FREQUENCY, CPS*	*AVERAGE TWIST LEVEL, tpi*	*TWIST PERIOD INCHES*	*PRODUCT*
11	15	2	25	alternating-twist yarn
12	25	1.3	15	alternating-twist yarn
13	30	1	13	alternating-twist yarn, interlaced reversal segments
14	35	0.7	11	alternating-twist yarn, interlaced reversal segments
15	40	0.4	9	interlaced alternating-twist yarn.
16	45	0.2	8	interlaced alternating-twist yarn.

It is apparent from the foregoing that as the traverse frequency increases, the product assumes increased interlaced character. At higher frequencies, an interlaced yarn per se is produced. The alternating-twist product having interlaced twist reversal segments is readily prepared at lower traverse frequencies by either twister-interlacer of Figure 23 or 24, or without traversing by using the twister-interlacer of Figure 22.

EXAMPLE VI

The twister of Example V is used to twist 34 filament 70 denier poly(hexamethylene adipamide) yarn after drawing. The yarn speed is 2150 ypm, the tension is 15 grams, and the traverse cycle frequency is 18 cps. The results at various air pressures are given in Table 6A.

TABLE 6A

RUN	*AIR PRESSURE psig*	*AVERAGE TWIST tpi*	*TWIST PERIOD INCHES*
17	20	1	72
18	30	1.5	72
19	40	2	72
20	60	2.2	72
21	80	2.3	72

Here the product is a uniform alternating-twist yarn. At increased fluid pressure, the alternating-twist level increases. At increased traverse cycle frequency, interlacing appears in the product.

Numerous process modifications or variations are possible within the framework of the foregoing examples. For instance, by employing continuous upstream heating or other forms of plasticizing with the intermittent processes of Example I, the average twist level in the yarn can be considerably increased with additional setting attendant on the subsequent cooling of or removal of plasticizer from the twisted yarn. With the continuous downstream application of size during intermittent twisting, the alternating-twist is set. Many novelty effects can be achieved by twisting plied yarns or staple yarns prepared from materials dyed different colours. A large number of useful products, all based on alternating-twist, can be prepared using multiple twisting techniques, wherein several twisters are disposed in one of two principal arrangements:

(1) The pyramidal array, wherein two or more yarns are separately twisted, then combined, and the resulting structure(s) twisted.

(2) The tandem array, wherein two or more twisters are arranged in series, the separate yarns being introduced into the bundle in a stepwise fashion, one at each twister. Numerous variations or permutations of these basic arrangements are pos-

sible. In any such arrangement, the later-encountered twisters should have larger yarn passageways in order to accommodate the progressively increased bulk or diameter of the yarn bundle. The individual twisters are preferably operated out of phase with respect to one another. The various products exhibit braided or cable-like structures which are very stable to tension because of their plied and balanced character. By varying the twisting frequencies, the direction of twisting, and the tension in the yarn, a wide variety of alternating twist braided yarns can be produced.

Alternating-twist yarns are useful in the place of conventional twisted yarn in numerous applications, primarily in warp and/or filling uses, or in tricot knitting. Yarns at average twist levels of from about 1 to about 5 tpi and at period lengths of from about 18 to 80 inches may be used to prepare plain weave, satin or taffeta fabrics substantially equivalent to the comparable fabrics prepared from ordinary twisted yarns. At an average twist level of less than about 1.5 tpi, dyed fabrics of exceptional uniformity and freedom from loom streaks, barre and the like, can be prepared. Numerous novelty fabrics can be prepared from alternating-twist yarns of high (greater than about 1.5 tpi) average twist level, taking advantage of the controlled variation in lustre and cross section characteristic of these yarns. Exceptionally high levels of alternating-twist are achieved by twisting the yarn, in a warp during weaving. Mechanical means are employed to "clamp" the twist at reversal points, permitting yarn having up to 50 or more average tpi and extremely acute reversals.

The process of this invention is of exceptional value in improving the handling characteristics of zero-twist yarn. By "zero-twist" yarn is meant yarn having no substantial true twist, excluding the omnipresent slight twist in the yarn resulting from normal handling, e.g. twist resulting when removing yarn from a stationary package or due to traversing the yarn, or the twist which results from passing the yarn over skewed or rotating guides, all of which, from a practical sandpoint, are negligible. Quills prepared from alternating-twist yarns exhibit improved take-off characteristics as compared with known zero-twist yarn, and yarn tensions remain practically constant throughout the take-off cycle. Beams prepared from alternating-twist yarn, twisted in the warp, can be backwound without the formation of filament "ringers," and with or without the retention of twist, the latter case permitting for the first time the backwinding of a warp of zero-twist yarn without resort to slashing or ordinary process twisting. Yarn having about 1 average tpi of stable alternating-twist exhibits at least a 10% reduction in the coefficient of friction, reducing wear against guides, pins, and the like, and permitting a corresponding improvement in yarn mechanical quality. The process of this invention, when employed during the drawing operation, results in improved yarn quality since broken filaments and the like are twisted back into the yarn bundle, eliminating subsequent "wraps" and "stripbacks." The instant process also serves, generally, to compact the yarn bundle, facilitating many of the conventional textile operations which follow. Many novelty yarns are produced by plying and plending yarns or staple fibres in accordance with this invention, particularly if the blend consists of material dyed different shades or colours. Similar novelty effects are obtained by applying alternating-twist to "side-by-side" monofilaments.

According to this invention at least 0.4 or 0.5 tpi average twist and preferably at least 1 tpi of alternating-twist is preferred to obtain the indicated improvements in zero-twist yarn handling characteristics; lower levels of twist result only in marginal benefit at best. Twist period lengths of about 16 feet or more are suitable. Note, however, that at a given level of twist, a decrease in twist period results in a corresponding reduction in the length of the twist reversal sections, hence the shorter twist periods are generally preferable.

The production of yarns of intermediate alternating-twist level (0.5-5.0 average tpi) has been exemplified. High levels of alternating-twist (greater than about 5 average tpi) are produced similarly, and very high levels (about 20 average tpi or more) are produced by intermittent size or adhesive application, which is accomplished utilizing the apparatus of Figure 7, employing therewith a reciprocating guide at 31, applicator roll 32, and eyelet guide 34, so that yarn 14 is alternately in and out of contact with applicator roll 32 (yarn positions 14 and 14a). The heating means 33 may also be used, as described earlier, to facilitate drying of the size or adhesive. In this method, superimposed secondary variations of twist are imposed on the product by the tension change in the yarn in moving from position 14 to position 14a. This effect also occurs with a traversing windup, and is used to advantage with the fluid twister of Figure 4. When such secondary variations of twist are to be avoided, idler roll 17 of Figures 5 and 6, which tends to "damp" such varying tensions, is used; conversely, to further this effect, that roll is usually omitted. In extending these principles, the process of this invention can be used with conventional twisted yarn to produce a product with stable alternating-twist, the net sum of which is greater than zero. Products so produced

have much higher uniformity than results from the known prior art procedures discussed above.

In addition to those described earlier, yarns useful in this process include those comprising filaments having "Y," cruciform, or otherwise modified cross-sections, since such yarns twist at a high rate owing to their irregular surface and high surface area. This process is quite useful with elastomeric yarns because of the very low operating tensions permitted during twisting. Yarn to be twisted may contain any of the usual textile additives, e.g. delusterants and anti-oxidants, and may be "finished" in accordance with accepted practice. Although a quite wide range of yarn denier and filament count may be used, e.g. from monofilaments to a tow, when extremely large or small yarn bundles are twisted, twister dimensions should be adjusted to the foregoing discussion.

Use of the fluid twister in accordance with the process of this invention is of considerable advantage in that such an apparatus is inexpensive, requires little maintenance owing to the absence of moving or rotating parts, and minimum yarn contact (no yarn degradation), is practically instantaneous in its action, e.g. when changing direction of twisting or during intermittent twisting, and is very economical to operate. Moreover, such twisters are readily adaptable to operate on extremely close centres, as required in warp twisting. When the twister conforms to the operable and/or preferred dimensions as indicated hereinabove, uniform and reproducible twisting is obtained.

The process of this invention permits yarn production at exceedingly high twisting rates and at exceedingly high throughput speeds over wide ranges of tension, including the very lowest. The susceptibility of the process to variations in process conditions during twisting permits a number of useful process departures from the more important embodiments of intermittent twisting, including production of alternating-twist by the controlled variation of such factors during continuous unidirectional twisting. The process may be employed at most stages of textile operations, such as during beaming, spinning, drawing, weaving, and the like. The various alternating-twist products, which exhibit a surprising degree of utility and twist retentivity, may be used in the place of conventional twisted yarn in numerous applications, resulting in considerable saving and increased production achieved with improved yarn quality, or to improve the handling or characteristic of zero-twist yarn, with comparable benefit. The process utilizing multiple vortex apparatus makes possible the production of a variety of products with essentially the same apparatus while utilizing a continuous supply of fluid. Alternating-twist yarns having sharp reversals and exceptional uniformity of twist profile, with or without interlacing of reversals, are prepared rapidly and continuously. The variety of apparatus utilizing the "multiple vortex" principle permits single or multi-end operations under a wide variety of process conditions, e.g. yarn speed and traverse cycle frequency. Fabrics prepared from yarns prepared in accordance herewith are characteristically more uniform.

Claim 14 of our Specification No. 871,112 claims a process for imparting a twist to a travelling filamentary material which comprises introducing the filamentary material axially into a yarn passageway having an equivalent diameter (as hereinbefore defined) of 0.002-0.125 inch, directing one or more gas streams having at least half sonic velocity into the yarn passageway in a non-axial direction against the periphery and eccentrically to the axis of the filamentary material while the latter is under tension not exceeding 25 grams, the ratio of the cross-sectional area of the yarn passageway to that of the gas stream or streams being from 4 : 1 to 1 : 10 (both areas being measured at the point of interception of the gas by the filamentary material) and the process conditions being such that the filamentary material is twisted at a rate of at least 50,000 turns per minute, in which process the gas enters the twist passageway in turn through two or more conduits that direct the fluid against the filamentary material in opposing directions. That subject matter is not claimed here.

WHAT WE CLAIM IS :—

1. Process for reproducing an alternate twist yarn which comprises subjecting a multifilament yarn under a controlled substantially constant tension in a yarn passageway to one or more streams of compressible fluid having at least half sonic velocity and exerting a twisting action on the yarn bundle as a whole, and varying one or more of the process conditions so that equilibrium twisting is substantially avoided.

2. Process according to claim 1, wherein the yarn is subjected to the action of the streams of compressible fluid in a yarn passageway having an equivalent diameter (as hereinbefore defined) of 0.002 to 0.125 inch, the ratio of the cross-sectional area of the yarn passageway to that of the fluid stream or streams being from 4 : 1 to 1 : 10, both areas being measured at the point of interception of the fluid by the filamentary material.

3. Process according to claim 1 or 2, wherein the yarn is traversed from side to side of the yarn passageway.

4. Process according to claim 3, wherein the yarn is subjected to the action of the streams of compressible fluid in a yarn pas-

sageway consisting of two or more adjacent yarn passages which have their longitudinal axes substantially parallel and which either overlap or are connected by a slot or slots through which the yarn can pass, and the yarn is traversed between the yarn passages.

5. Process according to claim 4, wherein the twisting action exerted on the yarn in one yarn passage is opposite in direction to that in the other yarn passage.

6. Process according to any one of claims 3 to 5 wherein the yarn is traversed at a rate less than 50 cycles per second.

7. Process according to claim 6, wherein the yarn is traversed at a rate less than 25 cycles per second.

8. Process according to any one of the preceding claims, wherein there is at least one fluid stream which exerts no twisting action on the yarn bundle as a whole when it is in its mean position.

9. Process according to any one of the preceding claims, wherein the speed at which the yarn is passed through the yarn passageway is varied

10. Process according to any one of the preceding claims, wherein the velocity of the or at least one of the fluid streams exerting a twisting action on the yarn bundle is varied.

11. Process according to any one of the preceding claims, wherein a plasticizing or sizing agent is applied intermittently to the yarn before it passes through the yarn passageway.

12. Process according to any one of the preceding claims, wherein the fluid streams are so disposed that they cause fluid vortices which are substantially parallel to the longitudinal axis of the running yarn.

13. Process according to any one of the preceding claims, wherein the yarn consists at least in part of continuous filaments.

14. Process according to any of the preceding claims, wherein the twisting fluid is air.

15. Process according to any of claims 1 to 13, wherein the twisting fluid is steam.

16. Process according to any of the preceding claims, wherein the yarn is initially of substantially zero twist.

17. Process according to any one of the preceding claims, wherein the alternating-twist is stabilised by the application of a size or by setting it in the filaments by means or other softening or plasticizing agency.

18. Process according to any one of the preceding claims, wherein the yarn tension is less than 30 grams.

19. Process according to claim 18, wherein the yarn tension is between 0.5 and 10 grams.

20. Process for producing an alternate-twist yarn substantially as described in any one of the foregoing Examples.

21. Alternate twist yarns obtained by a process claimed in any of the preceding claims.

22. An alternate twist multifilament yarn in which the net bundle twist is substantially zero containing successive sections of yarn which have bundle twist in opposite directions and in which the individual filaments are interlaced with each other, these sections being separated from each other by sections of yarn which have substantially zero bundle twist and in which the individual filaments are interlaced to an extent which is sufficient to stabilize the alternate twist in the yarn.

23. Apparatus for producing an alternate twist yarn by a process claimed in any one of claims 1 to 20, which comprises a yarn passageway, means for causing yarn to travel through the passageway, at least one fluid conduit which intercepts the yarn passageway and through which a stream of compressible fluid can be supplied to exert a twisting action on the yarn bundle as a whole, and means for varying the rate at which travelling through the passageway is twisted.

24. Apparatus according to claim 23, wherein the yarn passageway consists of two or more adjacent yarn passages which have their longitudinal axes substantially parallel and which either overlap or are connected by a slot or slots through which yarn travelling through the passageway can pass, and at least one fluid conduit intercepts each yarn passageway, the fluid conduits being adapted to maintain opposed vortices in adjacent yarn passageways.

25. Apparatus according to claim 23 or 24, wherein the means for varying the rate at which yarn travelling through the passageway is twisted comprises means for varying the velocity of the or at least one of the streams of compressible fluid.

26. Apparatus according to any one of claims 23 to 25, wherein the means for varying the rate at which yarn travelling through the passageway is twisted comprises means for traversing the yarn from side to side of the yarn passageway.

27. Apparatus according to claim 23, substantially as described by reference to, or as illustrated in, the accompanying drawings.

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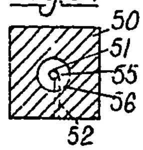
Fig. 1.

Fig. 2.



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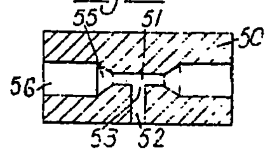

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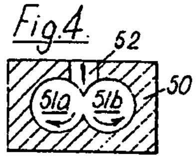

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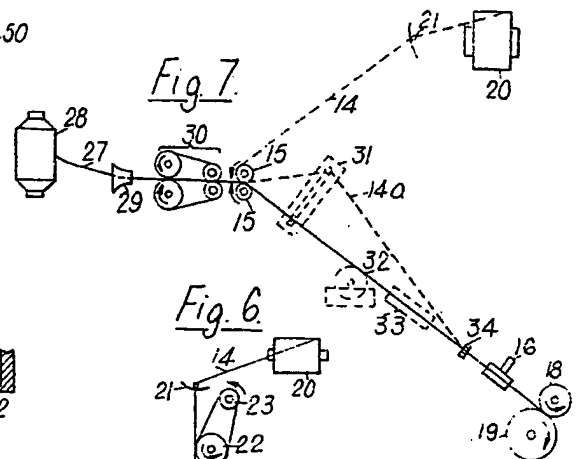

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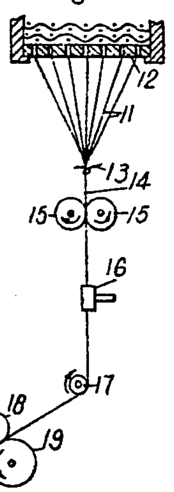

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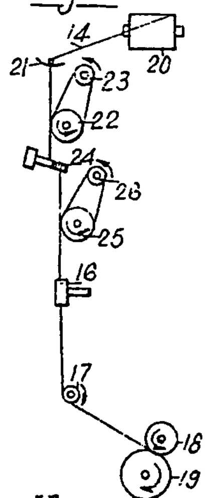

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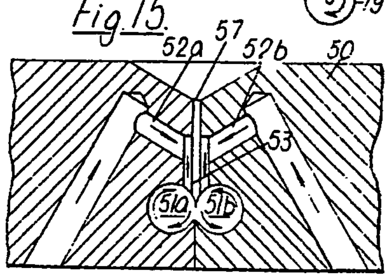


Fig. 1

Fig. 8

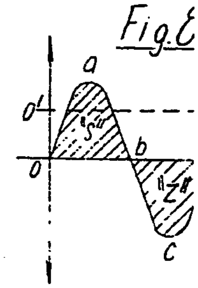
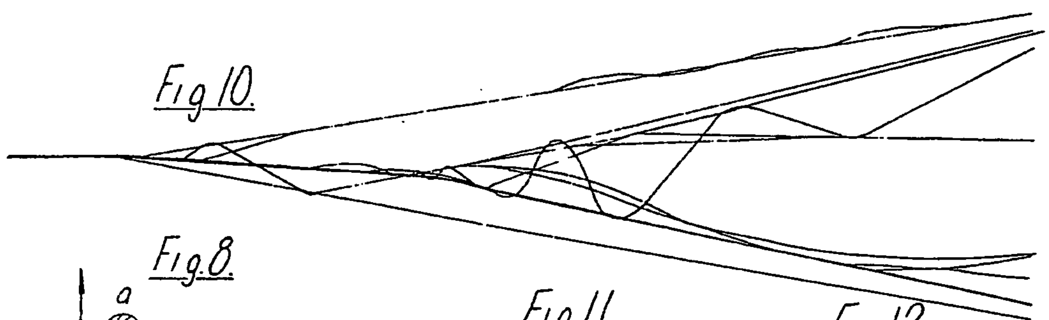


Fig. 9

924,088 COMPLETE SPECIFICATION
2 SHEETS

This drawing is a reproduction of the Original on a reduced scale.
SHEET 1

Fig 10.



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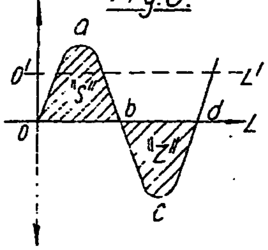

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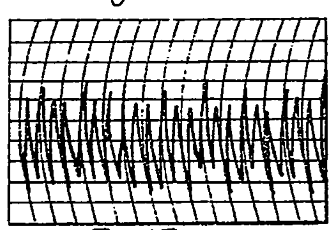

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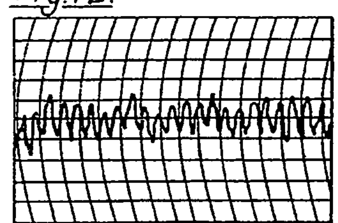
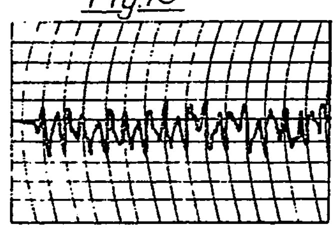


Fig 9

Fig. 13



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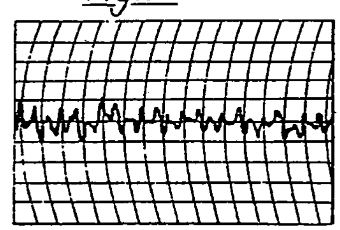

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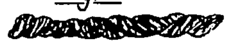

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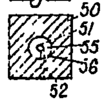

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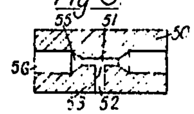

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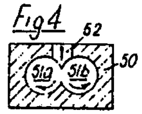

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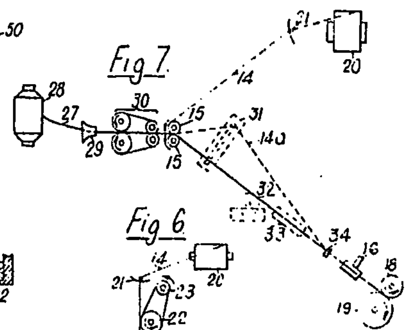

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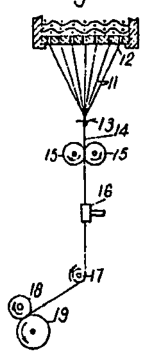

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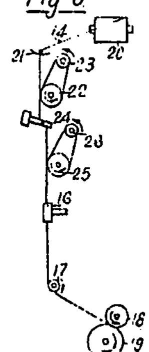

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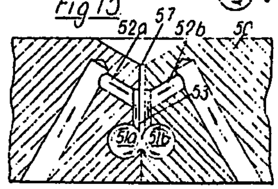

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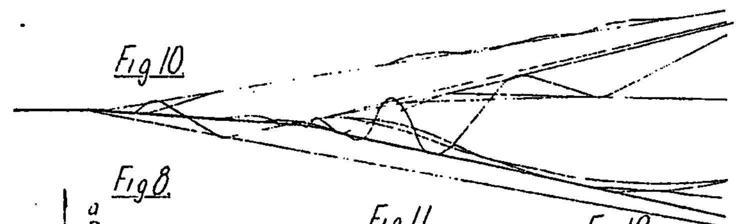

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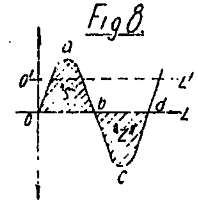

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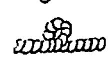

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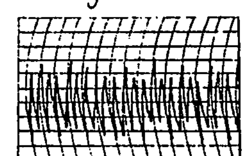

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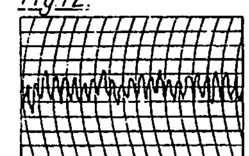

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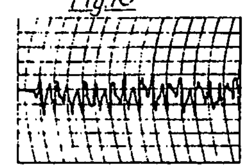

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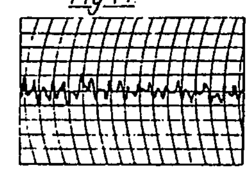

924,088 COMPLETE SPECIFICATION
2 SHEETS

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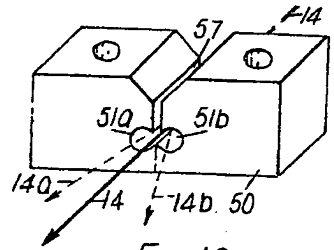
SHEET 2

Fig 16



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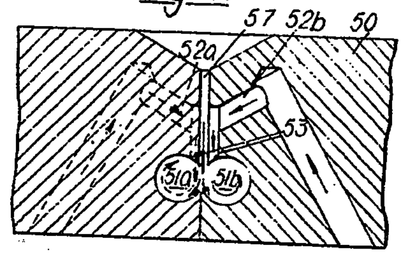

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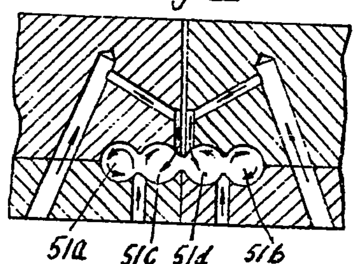

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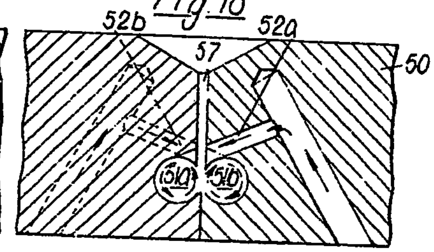

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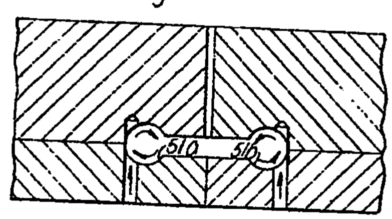

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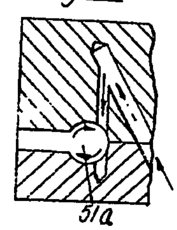

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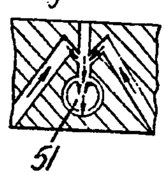

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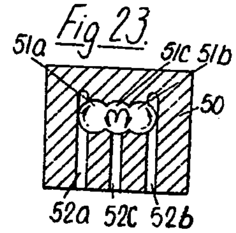

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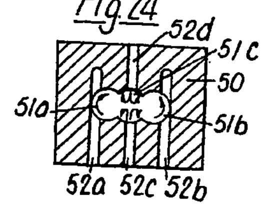

Fig. 25